

# IUPAC-IUB Joint Commission on Biochemical Nomenclature (JCBN) Nomenclature of glycolipids Recommendations 1997

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## GL-1. General considerations

Glycolipids are glycosyl derivatives of lipids such as acylglycerols, ceramides and prenols. They are collectively part of a larger family of substances known as glycoconjugates. The major types of glycoconjugates are glycoproteins, glycopeptides, peptidoglycans, proteoglycans, glycolipids and lipopolysaccharides. The structures of glycolipids are often complex and difficult to reproduce in the text of articles and certainly cannot be referred to in oral discussions without a nomenclature that implies specific chemical structural features.

The 1976 recommendations [1] on lipid nomenclature contained a section (Lip-3) on glycolipids, with symbols and abbreviations as well as trivial names for some of the most commonly occurring glycolipids. Since then, more than 300 new glycolipids have been isolated and characterized, some having carbohydrate chains with more than twenty monosaccharide residues and others with structural features such as inositol phosphate. The nomenclature needs to be convenient and practical, as well as extensible, to accommodate newly discovered structures. It should also be consistent with the nomenclature of glycoproteins, glycopeptides and peptidoglycans [2], oligosaccharides [3], and carbohydrates in general [4].

This document supersedes the glycolipid section in the 1976 Recommendations on lipid nomenclature [1].

## GL-2. Generic terms

**GL-2.1. Glycolipid.** The term glycolipid designates any compound containing one or more monosaccharide residues bound by a glycosidic linkage to a hydrophobic moiety such as an acylglycerol, a sphingoid, a ceramide (*N*-acylsphingoid) or a prenol phosphate.

**GL-2.2. Glycoglycerolipid.** The term glycoglycerolipid is used to designate glycolipids containing one or more glycerol residues.

**GL-2.3. Glycosphingolipid.** The term glycosphingolipid designates lipids containing at least one monosaccharide residue and either a sphingoid or a ceramide. The glycosphingolipids can be subdivided as follows:

- A) Neutral glycosphingolipids:
  - 1) mono-, oligo-, and polyglycosylsphingoids
  - 2) mono-, oligo-, and polyglycosylceramides.
- B) Acidic glycosphingolipids:
  - 1) sialoglycosphingolipids (gangliosides, containing one or more sialic acid residues)
  - 2) uronoglycosphingolipids (containing one or more uronic acid residues)
  - 3) sulfoglycosphingolipids (containing one or more carbohydrate-sulfate ester groups)

- 4) phosphoglycosphingolipids (containing one or more phosphate mono- or diester groups)
- 5) phosphonoglycosphingolipids (containing one or more (2-aminoethyl)hydroxyphosphoryl groups).

**GL-2.4. Glycophosphatidylinositol.** The term glycophosphatidylinositol is used to designate glycolipids which contain saccharides glycosidically linked to the inositol moiety of phosphatidylinositols (e.g. diacyl-*sn*-glycero-3-phosphoinositol), inclusive of lyso- (Lip-2.6 in [1]) species and those with various *O*-acyl-, *O*-alkyl-, *O*-alk-1-en-1-yl- (e.g. plasmalynositols; [5]) or other substitutions on their glycerol or inositol residues.

**GL-2.5. Psychosine.** Psychosine was coined historically to designate a monoglycosylsphingoid (*i.e.* not acylated). The use of this term is not encouraged (Lip-3.4 in [1]).

**GL-2.6. Other names.** Other terms such as fucoglycosphingolipid, mannoglycosphingolipid, xyloglycosphingolipid, etc., may be used when it is important to highlight a certain structural feature of the glycolipid.

### GL-3. Principles of nomenclature

**GL-3.1. Number of monosaccharide residues.** The number of monosaccharide residues in an oligosaccharide is indicated by suffixes such as "diosyl", "triosa", "tetraosyl" etc. [1, 6]. Thus, the general name for the oligosaccharide residue of all glycosphingolipids containing ten monosaccharide residues is "glycodecaosyl"; it might be a glycodecaosylceramide or a 3-glycodecaosyl-1,2-diacyl-*sn*-glycerol.

*Note 1.* "diosyl" not "biosyl" is the correct suffix.

*Note 2.* The "a" in "triosa", etc., is not elided in order to differentiate a tetrasaccharide residue (tetraosyl) from a four carbon sugar (tetrose), etc. The "a" in "triosa" is added for a similar reason.

Recommendations have been made for the nomenclature of oligosaccharides [3, 4].

**GL-3.2. Naming of monosaccharide residues.** Monosaccharide residues are named and abbreviated (Table 1) according to the proposed nomenclature recommendations for carbohydrates [4] (see also the nomenclature of glycoproteins [2]). The D and L configurational symbols are generally omitted; all monosaccharides are D with the exception of fucose and rhamnose which are L unless otherwise specified.

**GL-3.3. Use of symbols for defining oligosaccharide structures.** Using the condensed system of carbohydrate nomenclature (Ref. [2], section 3.7; Ref. [4], 2-Carb-38.5), positions of glycosidic linkages and anomeric configurations are expressed in parentheses between the monosaccharide residues that are thus linked. This principle should be adhered to in full names as well as the abbreviated structures. A "short form" for representing sequences more briefly can be used for specifying large structures. Positions of glycosidic linkages are still given, but the number of the anomeric carbon is omitted, since this is invariable for each monosaccharide, *i.e.* C-1 for Glc, etc.; C-2 for Neu5Ac, etc.

Example:

$\alpha$ -D-Galp-(1 $\rightarrow$ 3)- $\alpha$ -D-Galp- (extended form)  
or  
Gal( $\alpha$ 1-3)Gal( $\alpha$ - (condensed form)  
or  
Gal $\alpha$ 3Gal $\alpha$ - or Gal $\alpha$ -3Gal $\alpha$ - (short form).

**Table 1. Recommended abbreviations for some monosaccharides, derivatives and related compounds.**

Name	Symbol
<i>N</i> -acetylglucosamine	GalNAc
<i>N</i> -acetylglucosamine	GlcNAc
<i>N</i> -acetylneuraminic acid <sup>1</sup>	Neu5Ac or NeuAc
5,9- <i>N</i> , <i>O</i> -diacetylneuraminic acid <sup>1</sup>	Neu5,9Ac <sub>2</sub>
fucose (6-deoxygalactose)	Fuc
galactitol	Gal-ol
galactosamine	GalN
galactopyranose 3-sulfate	Galp3S
galactose	Gal
galacturonic acid	GalA
glucitol	Glc-ol
glucosamine	GlcN
glucose	Glc
glucose 6-phosphate	Glc6P
glucuronic acid	GlcA
<i>N</i> -glycolylneuraminic acid <sup>1</sup>	Neu5Gc or NeuGc
myo-inositol <sup>2</sup>	Ins
mannose	Man
4- <i>O</i> -methylgalactose	Gal4Me
rhamnose	Rha
xylose	Xyl

<sup>1</sup> Acylated neuraminic acids and other derivatives of neuraminic acid may also be called sialic acids (abbreviated Sia) when the nature of the *N*-acyl substituent(s) is not relevant, or is unknown [7].

<sup>2</sup> myo-Inositol with the numbering of the 1D configuration [8].

**GL-3.4. Ring size and conformation.** Ring size and conformation should be designated only when firmly established from NMR or other experimental data. Previously published recommendations on the specification of conformation should be consulted [9, 10].

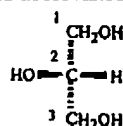
Example:

$\alpha$ -D-galactopyranosyl-<sup>4</sup>C<sub>1</sub>-(1 $\rightarrow$ 3)- $\alpha$ -D-galactopyranosyl-<sup>4</sup>C<sub>1</sub>-  
or  
Galp<sup>4</sup>C<sub>1</sub> $\alpha$ 3Galp<sup>4</sup>C<sub>1</sub> $\alpha$ -.

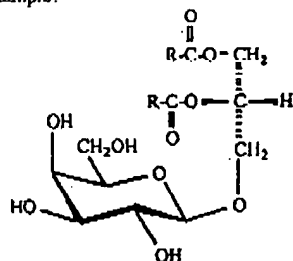
Subsequently, examples will usually be in the more traditional form with parentheses and both anomeric locants, as for example Gal( $\beta$ 1-4)Glc-, but it is understood that the short form (*i.e.* Gal $\beta$ 4Glc-) is also acceptable.

### GL-4. Classification of glycolipids based on their lipid moieties

**GL-4.1. Glycoglycerolipids.** Esters, ethers and glucose derivatives of glycerol are designated by a prefix, denoting the substituent, preceded by a locant. As previously discussed in detail [1], the carbon atoms of glycerol are numbered stereospecifically, with carbon atom 1 at the top of the formula shown below. To differentiate this numbering system from others that have been used, the glycerol is always accompanied by the prefix *sn* (for stereospecifically numbered, Lip-1.13 in [1]) in systematic and abbreviated names.



Example:

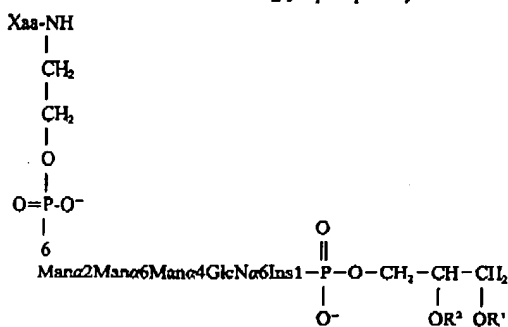


1,2-di-O-acyl-3-O- $\beta$ -D-galactosyl-*sn*-glycerol

#### GL-4.2. Glycophosphatidylinositols

4.2.1. Glycophosphatidylinositol (GPI) nomenclature should incorporate the accepted IUPAC-IUB recommendations [1, 2] for the naming of phospholipids and the glycan portions of glycolipids or glycoproteins. While the diversity of glycophosphatidylinositol structures is only beginning to be realized (for reviews see [11, 12]), many appear to have a common "core".

"Core" structure of glycophosphatidylinositols



Xaa = C-terminal residue

R = acyl, alkyl etc., side-chains

4.2.2. Glycophosphatidylinositols covalently attached to polypeptides are termed "GPI-anchors". Generally, such anchors are covalently attached to the C-terminus of a polypeptide via an amide linkage to 2-aminoethanol, which is linked to the terminal core mannose residue via a phosphodiester bond on O-6 of the mannose. A core Man<sub>2</sub>GlcNAc<sub>6</sub>Ins glycan structure is attached to the inositol (generally *D*-myo-inositol) of phosphatidylinositol. The non-acetylated GlcNAc is a characteristic feature of glycophosphatidylinositols. Anchor structures appear to vary considerably both in terms of modifications on the core glycan and with respect to additional modifications of the inositol residue. Free glycophosphatidylinositols have generically been termed "glycoinositolphospholipids" to distinguish them from those covalently attached to proteins or larger glycan structures.

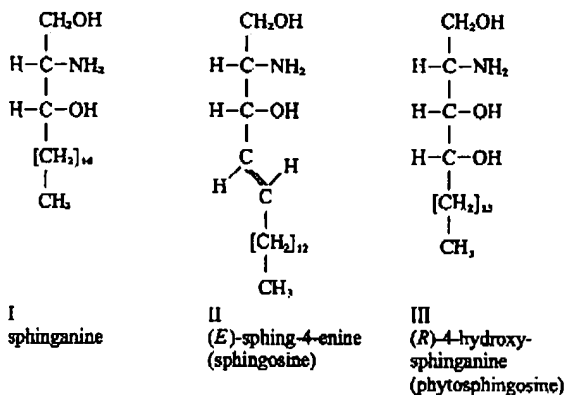
GL-4.3. Glycosphingolipids. 4.3.1. A glycosphingolipid is a carbohydrate-containing derivative of a sphingoid or ceramide. It is understood that the carbohydrate residue is attached by a glycosidic linkage to O-1 of the sphingoid.

4.3.2. Sphingoids are long-chain aliphatic amino alcohols. The basic chemical structure is represented by the compound originally called "dihydrosphingosine" [(2*S*,3*R*)-2-aminooctadecane-1,3-diol]. This sphingoid should now be referred to [1] as sphinganine (I).

The terms sphinganine, sphing-4-ene etc. imply a chain length of 18 carbon atoms. Chain-length homologs are named by the root chemical name of the parent hydrocarbon. For example, the sphingoid with 20 carbon atoms is icosasphinganine and the sphingoid with 14 carbon atoms is tetradecasphinganine.

Unsaturated derivatives of sphinganine and other sphingoids should be defined in terms of the location and configuration of each olefinic center. The most commonly occurring unsaturated sphingoid was originally called "sphingosine" [(2*S*,3*R*,4*E*)-2-aminooctadec-4-ene-1,3-diol]. It should now be referred to as (*E*)-sphing-4-ene (II). The trivial name "sphingosine" can be retained. As a second example, a C<sub>18</sub> sphingoid with two *trans* double bonds at 4,14 should be called (4*E*,14*E*)-sphinga-4,14-dienine.

Substituents such as hydroxy, oxo, methyl, etc. are referred to by appropriate suffixes that denote the position of each substituent. The sphingoid containing a hydroxyl group at C-4 of sphinganine was originally called phytosphingosine. According to the nomenclature adopted in 1976 [1], it should be called (2*S*,3*S*,4*R*)-2-aminooctadecane-1,3,4-triol. A trivial (but incorrect) name is (*R*)-4-hydroxysphinganine (III).



4.3.3. Ceramides are *N*-acylated sphingoids. The fatty acids of naturally occurring ceramides range in chain length from about C<sub>16</sub> to about C<sub>26</sub> and may contain one or more double bonds and/or hydroxy substituents at C-2. The complete chemical name for a specific ceramide includes the sphingoid and fatty acyl substituents. For example, a ceramide containing 2-hydroxyoctadecanoic acid and sphing-4-ene should be called (*E*)-*N*-(2-hydroxyoctadecanoyl)sphing-4-ene.

#### GL-5. Neutral glycosphingolipids

GL-5.1. Monoglycosylceramides. The trivial name "cerebroside" was historically used for the substance from brain,  $\beta$ -galactosyl(1 $\leftrightarrow$ 1)ceramide, and was later modified to include  $\beta$ -glucosyl(1 $\leftrightarrow$ 1)ceramide from the spleen of a patient with Gaucher's disease. It has become a general term for these two kinds of monoglycosylceramides. However, since other monosaccharides are found in this class, the more structurally explicit terms such as glucosylceramide (GlcCer or better, Glc $\beta$ 1Cer), galactosylceramide (GalCer), xylosylceramide (XylCer), etc. should be used.

GL-5.2. Disylceramides. Disylceramides may be named systematically, e.g.  $\beta$ -D-galactosyl-(1 $\leftrightarrow$ 4)- $\beta$ -D-glucosyl-(1 $\leftrightarrow$ 1)-ceramide. However, it is often more convenient to use the trivial name of the disaccharide and call the structure given above lactosylceramide (LacCer).



IV<sup>3</sup>-α-Neu5,9Ac2,II<sup>3</sup>-α-Neu5Ac-Gg4C6r.

lactosylceramide [17]-sulfate.

III<sup>4</sup>-E<sub>III</sub>-P-At3Cer

Gal $\beta$ 4GlcNAc $\alpha$ 4GlcA $\alpha$ 2Ins-1-*P*-Cer.

$$\text{H}_2\text{N}-\text{CH}_2-\text{CH}_2-\text{P} \begin{array}{l} \text{O} \\ \parallel \\ \text{OH} \end{array}$$
$$\begin{array}{c} \text{OH} \\ | \\ \text{NH}_2\text{CH}_2\text{CH}_2-\text{P}=\text{O} \\ | \\ \text{6} \\ | \\ \text{Gal4Me}\beta\text{3GalNAc}\alpha\text{3GlcNAc}\beta\text{2Man}\alpha\text{3Man}\beta\text{4GlcCer} \\ | \qquad \qquad \qquad | \\ \text{Fuc}\alpha\text{4} \qquad \qquad \text{Xvl}\alpha\text{2} \end{array}$$
IV<sup>3</sup>- $\alpha$ -GalNAc-Gb<sub>4</sub>Cet.

Though these designations are far from being systematic, and it is impossible to derive the structure from them, they have the advantage of being short and well understood since they have been in use for a long time. A list of these abbreviations is given in Table 3.

Table 3. Some abbreviations using the Svennerholm system.

Structure	Abbreviation*
Neu5Ac $\alpha$ 3Gal $\beta$ 4GlcCer	GM3
GalNAc $\beta$ 4(Neu5Ac $\alpha$ 3)Gal $\beta$ 4GlcCer	GM2
Gal $\beta$ 3GalNAc $\beta$ 4(Neu5Ac $\alpha$ 3)Gal $\beta$ 4GlcCer	GM1a
Neu5Ac $\alpha$ 3Gal $\beta$ 3GalNAc $\beta$ 4Gal $\beta$ 4GlcCer	GM1b
Neu5Ac $\alpha$ 8Neu5Ac $\alpha$ 3Gal $\beta$ 4GlcCer	GD3
GalNAc $\beta$ 4(Neu5Ac $\alpha$ 8Neu5Ac $\alpha$ 3)Gal $\beta$ 4GlcCer	GD2
Neu5Ac $\alpha$ 3Gal $\beta$ 3GalNAc $\beta$ 4(Neu5Ac $\alpha$ 3)Gal $\beta$ 4GlcCer	GD1a
Gal $\beta$ 3GalNAc $\beta$ 4(Neu5Ac $\alpha$ 8Neu5Ac $\alpha$ 3)Gal $\beta$ 4GlcCer	GD1b
Neu5Ac $\alpha$ 8Neu5Ac $\alpha$ 3Gal $\beta$ 3GalNAc $\beta$ 4(Neu5Ac $\alpha$ 3)-Gal $\beta$ 4GlcCer	GT1a
Neu5Ac $\alpha$ 3Gal $\beta$ 3GalNAc $\beta$ 4(Neu5Ac $\alpha$ 8Neu5Ac $\alpha$ 3)-Gal $\beta$ 4GlcCer	GT1b
Gal $\beta$ 3GalNAc $\beta$ 4(Neu5Ac $\alpha$ 8Neu5Ac $\alpha$ 8Neu5Ac $\alpha$ 3)-Gal $\beta$ 4GlcCer	GT1c
Neu5Ac $\alpha$ 8Neu5Ac $\alpha$ 3Gal $\beta$ 3GalNAc $\beta$ 4-(Neu5Ac $\alpha$ 8Neu5Ac $\alpha$ 3)Gal $\beta$ 4GlcCer	GQ1b

\* Previously written using subscripts, e.g. G<sub>MI</sub>, etc.

Since there is no clear-cut system in these abbreviations, it is not recommended to extend the list by coining new symbols of this kind. As a result, the following two cases are examples of abbreviations that should not be used.

- 1) A disialoganglioside, Neu5Ac $\alpha$ 3Gal $\beta$ 3(Neu5Ac $\alpha$ 6)GalNAc $\beta$ 4Gal $\beta$ 4GlcCer, has been abbreviated GD1a. This practice should be discontinued. The recommended abbreviation for this compound is IV<sup>3</sup>- $\alpha$ -Neu5Ac,III<sup>6</sup>- $\alpha$ -Neu5Ac-G<sub>G</sub>Cer.
- 2) The system has been extended to gangliosides of other "root" types, such as those derived from lactotetraosylceramide. An example of this kind is the widely distributed ganglioside called sialoparagloboside, Neu5Ac $\alpha$ 3Gal $\beta$ 4GlcNAc $\beta$ 3-Gal $\beta$ 4GlcCer, which has at times been abbreviated LM1, but should be referred to as IV<sup>3</sup>- $\alpha$ -Neu5Ac-nL<sub>C</sub>Cer.

Attempts to abbreviate more complex glycosphingolipids derived from these examples have resulted in other illogical abbreviations, such as Fuc-3'-LM1 for Neu5Ac $\alpha$ 3Gal $\beta$ 4(Fuc $\alpha$ 3)GlcNAc $\beta$ 3Gal $\beta$ 4GlcCer (IV<sup>3</sup>- $\alpha$ -Neu5Ac,III<sup>6</sup>- $\alpha$ -Fuc-nL<sub>C</sub>Cer).

More information on the structures of various glycolipids and the biological material from which they were obtained may be found in several reviews [14–16].

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